THE APSIS EXPERIMENT: SIMULATING TITAN'S UPPER ATMOSPHERE AND ITS PHOTOCHEMISTRY IN THE VACUUM ULTRA-VIOLET (VUV)

Sarah Tigrine, Nathalie Carrasco, Ludovic Vettier, Laurent Nahon

▶ **To cite this version:**

Sarah Tigrine, Nathalie Carrasco, Ludovic Vettier, Laurent Nahon. THE APSIS EXPERIMENT: SIMULATING TITAN'S UPPER ATMOSPHERE AND ITS PHOTOCHEMISTRY IN THE VACUUM ULTRA-VIOLET (VUV). Atelier KIDA 2015 (Kinetic Database for Astrochemistry), May 2015, Paris, France. hal-01176503

HAL Id: hal-01176503
https://hal.science/hal-01176503

Submitted on 15 Jul 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

THE APSIS EXPERIMENT: SIMULATING TITAN'S UPPER ATMOSPHERE AND ITS PHOTOCHEMISTRY IN THE VACUUM ULTRA-VIOLET (VUV)

S. TIGRINE[1,2,*], N. CARRASCO[1], L. VETTIER[1], L. NAHON[2]

[1]LATMOS, Université Versailles St. Quentin, UPMC Univ. Paris 06, CNRS, 11 Bvd. d'Alembert, 78280 Guyancourt, France, [2] Synchrotron SOLEIL, l'Orme des Merisiers, St Aubin, BP 48, 91192 Gif sur Yvette Cedex, France (*sarah.tigrine@latmos.ipsl.fr)

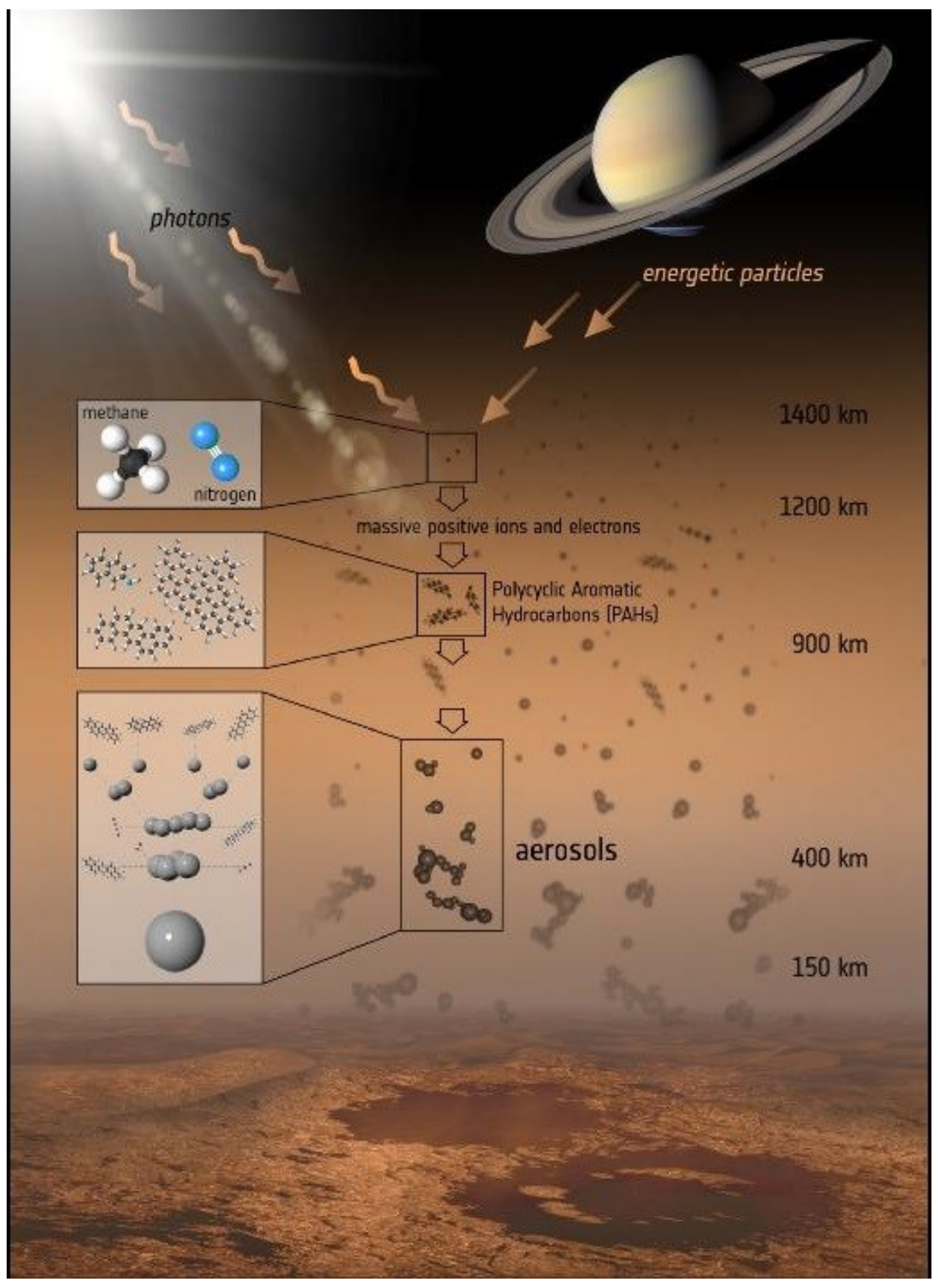
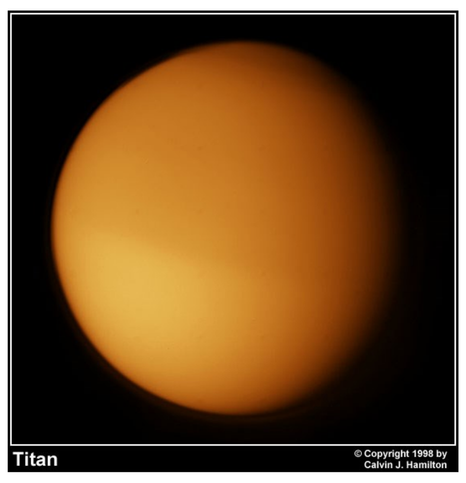


Figure 1: Aerosol formation in Titan's upper atmosphere



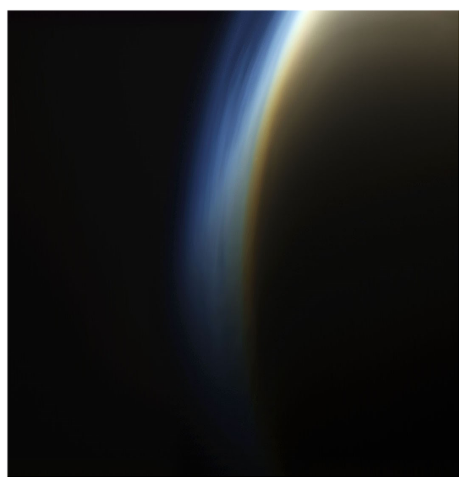


Figure 2 and 3: Titan seen by the Cassini's imager

Credits: NASA

TITAN'S UPPER ATMOSPHERE

Titan, the largest moon of Saturn, has a dense atmosphere whose upper layers are mainly composed of methane (CH_4) and molecular nitrogen (N_2). The Cassini mission revealed that the interaction between those molecules and the solar VUV radiation, as well as the electrons from Saturn's magnetosphere, leads to a complex chemistry above an altitude of 800km [1]; [2]; [3]; [4].

This naturally ionized environment contains heavy organic molecules like benzene (C_6H_6) even at altitudes higher than 900 km [5]. This is consistent with an initiation of the aerosols in Titan's upper atmosphere. Moreover, some N-bearing molecules of pre-biotic interest such as NH_3 have been detected by the instruments; but in quantities that do not match the theoretical models [3]; [6] .

The presence of those molecules makes Titan a natural laboratory to witness and understand prebiotic-like chemistry but despite all the data collected, all the possible chemical processes in such a hydrocarbon-nitrogen-rich environment are not precisely understood.

THE APSIS EXPERIMENT

Atmospheric Photochemistry SImulated by Synchrotron

In order to reproduce the photochemistry occurring in this kind of upper atmospheres, we designed a gas reactor named APSIS. This reactor is to be coupled with a VUV photon source as N_2 needs wavelengths shorter than 100 nm in order to be dissociated.

Two options regarding the VUV source are available for this experiment.

1. The DESIRS beamline at the synchrotron SOLEIL facility which is to be tuned at specific wavelengths in order to test different photochemical regimes and measure their impact.
2. At the LATMOS laboratory, a surfatron source has been developed using noble gases in a micro-wave discharge (figure 4). For example, neon has two resonance lines at 73.5 and 74.3 nm which allow us to dissociate and/or ionize both CH_4 and N_2.

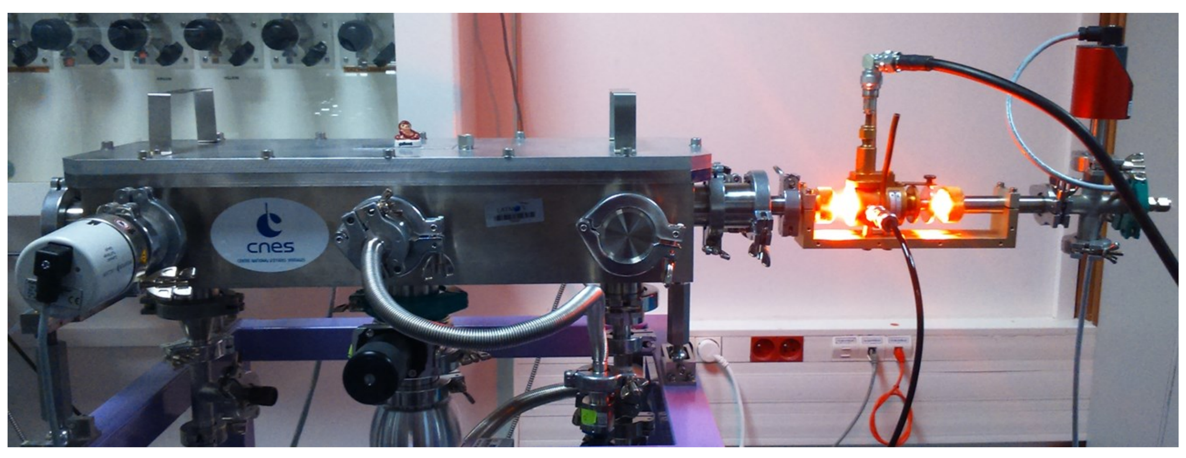


Figure 4: The LATMOS VUV source coupled to the APSIS reactor

MODELING THE EXPERIMENT

In parallel, a numerical ion-neutral coupled model has been developed regarding the parameters of the APSIS reactor [7].

This 0-D model takes into account the whole gas-phase chemistry occurring in a nitrogen-methane environment at ambient temperature (300K):

Photolysis, neutral reactions, ion-neutral reactions and dissociative recombinations.

Moreover, uncertainties on both the rate constants and the branching ratios are included in this simulation.

This numerical tool helps us to interpret our results taking into account the possible chemical reactions and their kinetic data available in complementary databases, among them the KIDA database.

For example, it was found that C_2H_2 is the more efficient neutral precursor for ionic growth in the system (figure 6).

EXPERIMENTAL RESULTS

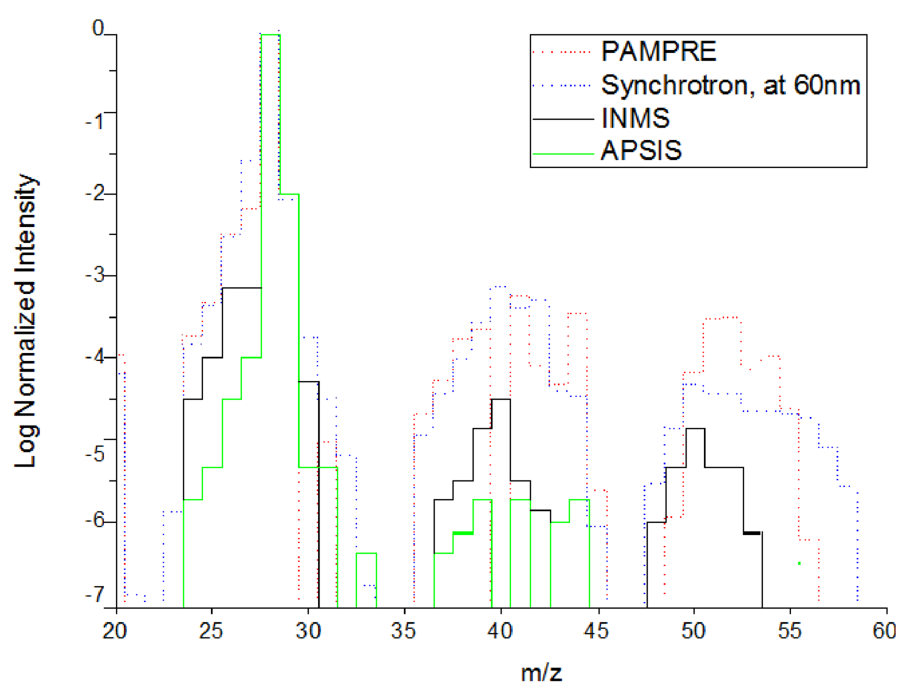


Figure 5: Comparison of data between the APSIS experiment [8], the Cassini space mission (instrument INMS), a previous synchrotron experiment (Imanaka, 2007) and a plasma-discharge Titan-like experiment.

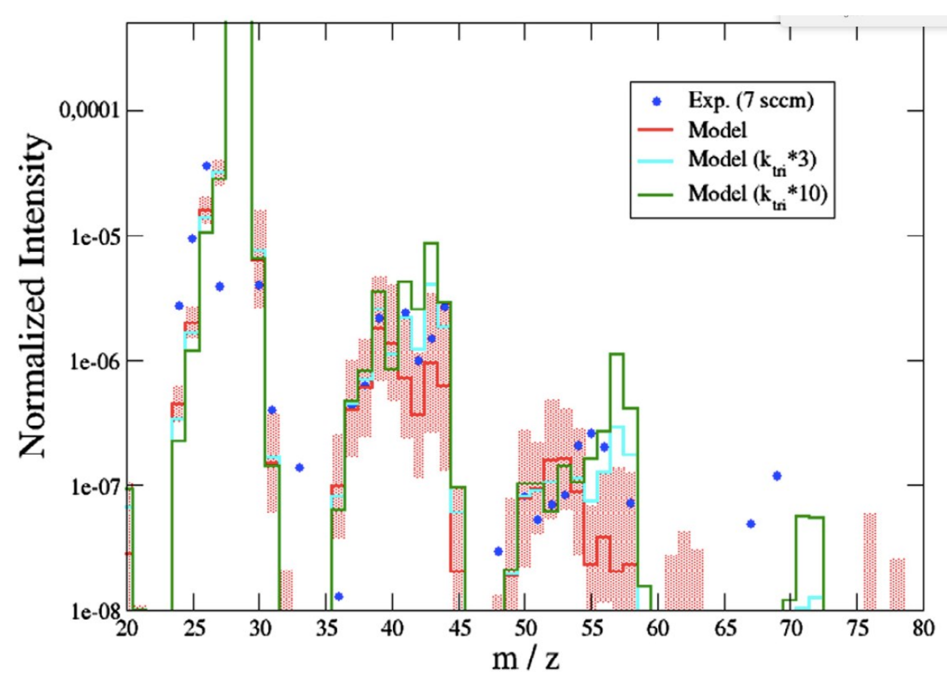


Figure 6: Comparison between the numerical model and results from APSIS.

The APSIS reactor has already been coupled to a synchrotron VUV light (DISCO beamline at SOLEIL) [8]. The results showed evidences of N-bearing products, such as HCN, but the production rates were low, especially when compared to data from another synchrotron experiment [9] or from the INMS/Cassini instrument (figure 5).

The experimental platform is still going through several technical developments in order to enable the production and detection of heavier compounds (with more than 4 heavy atoms) which we know are present in the upper atmosphere of Titan.

1. Carrasco, N., et al., *Uncertainty analysis of bimolecular reactions in Titan ionosphere chemistry model.* Planetary and Space Science, 2007. **55**(1): p. 141-157.
2. Cravens, T., et al., *Composition of Titan's ionosphere.* Geophysical Research Letters, 2006. **33**(7).
3. Vuitton, V., R. Yelle, and M. McEwan, *Ion chemistry and N-containing molecules in Titan's upper atmosphere.* Icarus, 2007. **191**(2): p. 722-742.
4. Waite, J.H., et al., *Ion neutral mass spectrometer results from the first flyby of Titan.* Science, 2005. **308**(5724): p. 982-986.
5. Waite, J., et al., *The process of tholin formation in Titan's upper atmosphere.* Science, 2007. **316**(5826): p. 870-875.
6. Krasnopolsky, V.A., *A photochemical model of Titan's atmosphere and ionosphere.* Icarus, 2009. **201**(1): p. 226-256.
7. Peng, Z., N. Carrasco, and P. Pernot, *Modeling of synchrotron-based laboratory simulations of Titan's ionospheric photochemistry.* GeoResJ, 2014. **1**: p. 33-53.
8. Peng, Z., et al., *Titan's atmosphere simulation experiment using continuum UV-VUV synchrotron radiation.* Journal of Geophysical Research: Planets, 2013. **118**(4): p. 778-788.
9. Imanaka, H. and M.A. Smith, *Role of photoionization in the formation of complex organic molecules in Titan's upper atmosphere.* Geophysical research letters, 2007. **34**(2).